*Agroforestry Systems* **56:** 89–105, 2002.



# Tree planting by small producers in the tropics: A comparative study of Brazil and Panama

Cynthia S. Simmons[1,*], Robert T. Walker[2] and Charles H. Wood[3]
*[1]Department of Geography, Central Michigan University, Dow Science Building, MI 48859 Mt. Pleasant, US; [2]Department of Geography, Michigan State University, 314 Natural Science Building, MI 48824-1115 East Lansing, US; [3]Center for Latin American Studies, University of Florida, 319 Grinter Hall, P.O. Box 115530, FL 32611 Gainesville, US; *Author for correspondence (e-mail: cynthia.simmons@cmich.edu; Phone: 989-774-2784)*

Received 9 October 2001; accepted in revised form 25 March 2002

*Key words:* Brazil, Land tenure, Panama, Reforestation, Small farmers, Tropical forest

## Abstract

Forest regrowth is a notable phenomenon across the tropical forest latitudes. Such reforestation takes place in the wake of land abandonment, occurs cyclically in a rotational agricultural system, and may result from the deliberate planting of trees by farmers. Although less extensive than successional forest regeneration, tree planting by small farmers can have potentially important environmental impacts at both the site and global scale. This paper examines tree-planting efforts by small farmers in the tropical frontier regions of Panama and Brazil in order to gauge the magnitude of reforestation activities, and to identify factors that influence these efforts. This paper discusses the environmental regulations, forestry law, and tenure institutions in both countries, and performs a comparative analysis of reforestation efforts with information derived from household surveys (n = 356) and in-depth tree planting interviews (n = 35). Results from logistic regression are also presented. Our results show that tree planting occurs more frequently in Panama, which we attribute to greater external support in the provisioning of extension and materials and strong market incentives. We suggest that the proximity of the study sites to Panama City facilitates external support and market drivers. Finally, our results suggest that land tenure security is an influential determinant of reforestation activities in both countries.

## Introduction

Recovery of agricultural lands by forest has been observed in many parts of the world, particularly in the developed, temperate countries, where trends this past century have been toward forest restoration in the aggregate (Walker 1993; Rudel 1997). Reforestation is also widespread in developing countries despite overall forest loss. The pace of such regrowth is pronounced in the Brazilian Amazon, for example, which has exhibited the highest absolute rate of tropical deforestation over the past thirty years.[1] Similar accounts have been reported in Central America (Simmons 1997).

Reforestation may occur naturally as a successional process, with abandonment of fields or farms in the wake of outmigration, farm failure, and aging of the household and its inescapable reduction in family labor. In addition, cyclic reforestation is found in the system of slash and burn agriculture, since secondary forest, or regrowth, is organized into stable age cohorts that serve as fertility inputs to crop production (Walker 1999). Regrowth also occurs when farmers partake directly in the planting of seedlings or saplings. While less extensive than reforestation due to succession, tree planting reduces the demand to open virgin lands, minimizes the degree of ecological disturbance at the farm site, and provides a means of enhancing land value. This paper addresses such

[1] In a classification of 267,000 hectares in the eastern sector of the Brazilian Amazon, Moran et al. (1996) demonstrate that the area of secondary succession increases from 11 to 32% between 1985 and 1991.

deliberate reforestation on part of small producers in tropical frontier areas of two countries, Brazil and Panama.

Brazil and Panama represent two contrasting situations with respect to forest resource bases, and bracket the range of salient characteristics potentially influencing the decision-making of small producers, particularly as they relate to market access, resource scarcity, and strength of legal institutions. Brazil possesses extensive forest resources located at a considerable distance from major population concentrations. By way of contrast, Panama is small and its forest resources are relatively exposed to population pressure from a primate city with more than a million inhabitants. The goal of this paper is to consider tree planting activities of small producers in these two extreme cases, and to address the factors influencing such efforts.

The paper is organized as follows. Section 2 addresses tree planting from a theoretical perspective, and considers environmental regulation and forestry law in Panama and Brazil. In addition, tenure institutions in both countries are examined. Section 3 presents results from two sets of household surveys conducted in the frontier reaches of Panama and Brazil. One is a statistical sample used to model tree planting behavior. The other is a smaller sample used to provide descriptive context for such activities in the study regions. This non-statistical sample comprises focused interviews undertaken with farmers who reforest, indicating species planted, techniques used, and the role of governmental and non-governmental support. Section 4 provides a comparison and contrast of the cases in Brazil and Panama, emphasizing important factors that contribute to tree planting. Section 5 concludes the paper with policy implications.

## The decision framework and institutional considerations

The decision to plant trees is essentially an economic decision to incorporate trees into a farming system. This is relatively infrequent among small producers in the absence of governmental inducements to do so, either through the provision of subsidies or requirements of the law. Such inducements have been rare in the Brazilian case, although a variety of non-governmental organizations are concerned about reforestation and are actively involved in promoting it.[2] Panama, on the other had, has taken a more proactive role in encouraging small producers to plant trees. In particular, government law requires a fixed reforestation effort per individual tree cut and removed in logging operations, and agencies have provided seeds, saplings, and technical extension to both colonists and indigenous peoples in efforts to restore forest cover (Simmons 1997).

Other factors that may contribute to tree planting, beyond economic motivation and legislation, include labor availability (Fortmann 1985; Godoy 1992; Thacher et al. 1997), access to credit and marketing assistance (Godoy 1992), social organization and institutions (Uphoff 1986; Cernea 1989; Ostrom 1990), and tenure security (Raintree 1987; White and Runge 1994; Unruh 1995; Walters et al. 1999). Of these, tenure security is perhaps the most widely cited essential ingredient for the success of any type of conservation effort. In the case of reforestation, both tree and land tenure must be considered. Without such security, small farmers will be hesitant to invest time and money in tree planting efforts (Fortmann 1985). The discussion to follow presents the economic rationale for tree planting, and considers the legal framework and tenure institutions that may influence these activities.

### *Tree planting economics for small producers*

The fundamental model of forestry economics, attributed to Faustmann, is focused on the maximization of profits over an infinite time horizon. Faustmann (Hirshleifer 1970) defined the present value of an infinite series of forest harvests as $PV = q + \delta^a([f(a) + q]) + \delta^{2a}([f(a) + q]) + \delta^{3a}([f(a) + q]) + \ldots$ where PV represents present value, $q$ is a planting/preparation cost, $\delta$ is a discount factor, $a$ is time, and $f(a)$ is a biomass or value function indicating tree growth. The geometric series yields $q + ([\delta^a/(1 - \delta^a)])([f(a) + q])$, and its optimization in $a$ is the "Faustmann problem" (Mitra and Wan 1985).

In fact, the growth rates of many tropical trees, particularly hardwoods, are too slow to generate competitive economic returns. This is not to say that forestry represents a "bad" investment in tropical coun-

[2] Walker and Wood (1998) (unpublished) showed a limited tree-planting incidence of 6% on 315 small producer lots along the Transamazon Highway in the State of Pará, Brazil.

tries, and there are many plantations throughout the world that prove the point. Such plantations, however, often focus on rapidly growing trees such as pine and eucalyptus. To the contrary, small producers, particularly in Brazil, are experimenting with slow-growing tropical hardwoods such as Mahogany and Brazilnut (Browder et al. 1996; Smith et al. 1996; Walker and Wood 1998 (unpublished)).[3]

Growth rates of these trees can be estimated by considering the biomass accumulation of secondary forests, to provide some measure of proportionate growth rates of commercial hardwood under low levels of silvicultural treatment. Uhl (1987) found that above ground biomass accumulates at 6.77 t $ha^{-1}$ $yr^{-1}$ for the first five years of succession following clearance in Venezuela; after five years, total biomass including roots was 38.1 t $ha^{-1}$. Saldarriaga et al. (1988) also show for sites in Venezuela that above ground biomass averages 58 t $ha^{-1}$ for 10 year old stands, 110t $ha^{-1}$ for 40 year old stands, and 150t $ha^{-1}$ for stands ranging in age between 60 and 80 years. Mature forest biomass above ground averages 255 t $ha^{-1}$. For the Bragantine region of the Eastern Amazon in Brazil, Vieira et al. (1996) estimate that secondary forest of five years accumulates 13.1 t $ha^{-1}$ of biomass above ground. Accumulations for ten, twenty, and forty year-old regrowth are 43.9, 80.5, and about 105t $ha^{-1}$, respectively. Mature forest possesses 265.7 t $ha^{-1}$ of biomass (Vieira et al. 1996).

Considering that primary forest species establish slowly in the shade of the pioneer canopy and do not become important components of the community for about 50 years (Saldarriaga and Uhl 1990), one estimate of hardwood growth rates may be taken from the later phases of the measures from Saldarriaga et al. (1988). In particular, between 40 and 70 years after the onset of succession, biomass accumulation is 40t $ha^{-1}$; if exponential growth is assumed over the 30 year period, the biomass (and value) accumulation rate is calculated at 12%.[4] Such a rate is in all likelihood a physical improbability in an agricultural area. Survey work along the Transamazon Highway suggests nearly 30% of farmers experience fire contagion from neighbors. This translates into an expected growth rate across individual properties of approximately 8%, assuming a fire damage affecting at least 30% of farmers. Such a number in turn is likely to be unobtainable, given added agronomic risks of pest infestation, as well as the economic uncertainty generally observed in forest frontiers (Alston et al. 2000).

Thus, returns to hardwood forestry under the silvicultural treatments of small producers are not likely to generate high present values, as defined in the Faustmann model. This suggests that Faustmann is probably not applicable in the present context. Indeed, profit maximization may not provide a good behavioral model in the frontier environment under any circumstances, given the lack of markets and the weakness of property institutions (Ellis 1993; Alston et al. 2000). Clearly, small producers will plant trees when compelled to do so independently of any economic rationale. But there does appear to be a substantial amount of tree planting that occurs outside the long arm of the law.

Consequently, we hypothesize the presence of a behavioral motivation other than profit maximization, namely welfare maximization (Walker 1999). Welfare maximization may be dependent on profit maximization (Singh et al. 1986) when markets for inputs and outputs are accessible. But in their absence, households still seek to achieve high levels of welfare given their factor endowments (land, labor, and capital) and attitudes toward risk (cf Chayanov Thorner et al. (1986) and Ellis (1993), Homma et al. (1996), Walker et al. (2002)). In the present setting, a household welfare function can include preferences such as the amenity value of forest (which may be functional, aesthetic, or ethical), the desire to leave a resource bequest for future generations, and attitudes towards risk, which may lead to crop diversification given environmental uncertainty.[5] Such preferences are presumably linked to human capital acquisition (age of household head, number of years of schooling), as well as household structure. This paper presents results of a statistical analysis of tree planting based on the specification of a household welfare function and the theory of choice (McFadden 1974). Walker et al.

[3] The sale of Brazilnut wood was banned until 1995, at which time it became permissible to sell the wood of dead trees.

[4] This is calculated by solving for the growth rate, $r$, in $(e^{r30} - 1) = 40$, given 30 years to achieve an accumulation of 40 tons (per hectare). Subtracting 1 from the exponential normalizes the starting time to zero biomass.

[5] Small producers in our study samples in both Brazil and Panama refer to the beauty of the forest and their desire to leave part of it behind for their children.

(2002) have implemented a similar specification in explaining farming system choices in the Brazilian Amazon.

*Legal considerations*

Besides personal considerations based on subjective preferences and economic necessity, small producers also respond to the law, which clearly affects their decision-making when it comes to tree planting. Brazil and Panama ascribe to the norms of forest law observed throughout Central and South America in seeking to legislate public control of externalities linked to land management and forest loss. Brazilian law focuses on the maintenance of existing forest and defines the limits of deforestation allowable on privately held lands. Panamanian law also attempts to regulate the extent and viability of existing forest, and recent legislative initiative has paved the way to proactive efforts to return degraded areas to forest cover. For instance, Federal Law 24 (23.11.92) and executive decree 89 (8.6.93) define a broad suite of state incentives to encourage reforestation in Panama. Tax exemptions in rents (article 4), investments (article 5), imports (article 6), and property (article 7) are permitted so long as they derive from, serve, or are linked to tree planting. In addition, the law establishes a mechanism for subsidizing interest rate reductions on loans for investments in such activities (article 9). The legal framework also seeks to protect reforestation efforts from land invasion (article 13) and natural hazards such as fire and disease through investments in extension activities (article 14).

The Brazilian forest code is based on Federal Law 4.771 (15.9.65), modified administratively to facilitate the harvesting of (dead) Brazilnut trees (Portaria 48/95 of IBAMA; 11.7.95) and to augment forest reserve areas in the Amazonian Region (Medida Provisoria 1.51 1, by presidential decree) from 50 to 80% on private lands. Brazil's code seeks to establish forests of permanent protection, which are treated in articles 2, 3, 26, and 31, but does not elaborate an extensive set of reforestation incentives, as is found in Panama. Nevertheless, article 18 of the Brazilian forest code may be interpreted as mandating state-initiated tree planting on private lands when human actions have resulted in the degradation of forest cover essential to the protection of soil and water quality. However, article 18 guarantees private owners freedom from appropriation and guarantees indemnity if lands to be recuperated are already under crops (See Machado (1995)).

Brazil has signed Goal 2000 promoted by the International Organization of Tropical Wood Exporters, which commits the forest products industry to export only wood extracted from managed lands by the year 2000. Pursuant to the international agreement, Decree no. 1.282 (19.10.95) outlines procedures and requirements for implementation. The prescribed management systems target rotation cycles of 30 to 35 years. Given the property sizes generally available and the installed capacity of sawmills in the Amazonian region, such cycles may prove difficult to achieve, in which case forest enrichments or plantation style plantings would provide additional source materials in the face of supply constraints. Consequently, the agreement may pave the way to reforestation incentives.

Panama and Brazil both recognize the importance of forest cover and the need to encourage reforestation. Be this as it may, much of the legislative framework in both of the countries appears aimed at large landholdings and explicitly corporate activity. While land ownership patterns in Panama and Brazil show strong concentration, much land cover in both countries is under the management of small producers. Consequently, the composition of the forest is dependent on the production systems and tree planting of small farmers.

*Tenure security*

The third critical factor possibly impacting tree planting activities is the confidence farmers have in the security of their land holding. Given the length of time required for trees to grow, a prime incentive for tree planting to occur is that the person who plants the trees will be sure to reap the rewards, which is only possible with a secure property institution (Walker 1987).

The strength and scope of tenure security varies across regions (Unruh 1995). In the Brazilian case, tenure security includes both legal and squatters (posse) rights to the land, and to the trees and crops planted. The main stipulation for tenure, as stated in the "beneficial use" clause in the Brazilian constitution, is that land must be kept in production in order for the government to recognize and enforce legal title. In 1971 the military government enacted decree 1164, shifting jurisdiction of a 100 km strip of land on both sides of all federal highways in the Brazilian

Amazon from the State to the Federal Government, and giving administrative responsibility to the National Institute of Colonization and Agrarian Reform (INCRA). Today, much of the land along these highways has been privatized, yet substantial areas are considered government land.

There are several options for individuals to acquire land in the Brazilian Amazon. One way is to purchase it from the owner and obtain legal title by registering the transfer with INCRA. An alternative strategy, one that is often employed, is for an individual to squat on private or public land, and then petition the government to recognize their "direito de posse" (squatter's rights). On government land, or *terras devolutas*, squatters can receive usufruct rights if the land is kept under production for one year and one day. If the land is kept under production for five consecutive years they can obtain legal title. In addition, article 191 of the 1988 constitution dictates that individuals who occupy private land and keep it under production for more than 5 years without opposition from the owners can obtain title through "adverse possession." Hastening the transfer time, the government may deem that privately held land is not being put to its "beneficial use" and subject it to expropriation for agrarian reform purposes.

A similar tenure arrangement is found in Panama, which provides both public and private land tenure arrangements. Panamanian legal code grants landowners the right to use, enjoy, and plan the disposition of their land as long as its meets the *social function*. Like Brazil, article 30 of the Panamanian Agrarian Code requires that land meet a *social function*, mandating that two-thirds of the land be under cultivation or planted in hardwood trees, and, if in pasture, there must be at least one animal for every two hectares. If land does not meet this criterion the government can expropriate it. An individual can receive private title to land by purchasing it from the owner and registering the title transfer with the Public Land Registry. However, article 65 stipulates that the land must meet its social function within a two year time period or it is subject to state expropriation. Another way to acquire land is for an individual to solicit title to public land, as expressed in article 12 of the agrarian code. A *titulo gratuito* (free title) is provided to those farmers who cannot afford land registration fees and agree to personally work the land. A *titulo oneroso* (paid title) is provided at a cost, but without the requirement that the owner work the land.

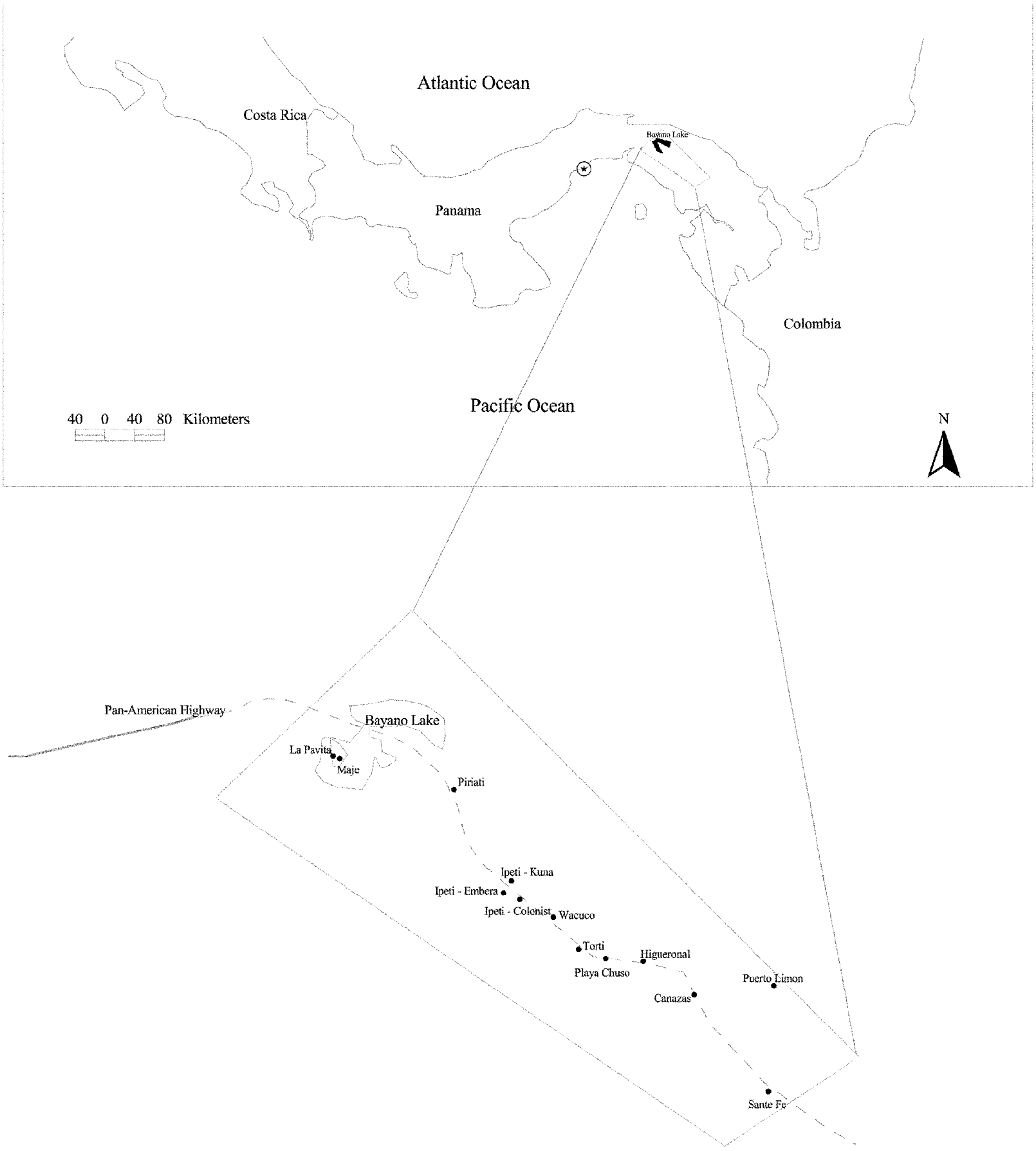
Land title in Panama is also categorized as provisional or definitive. Provisional title is granted on land that exceeds 50 hectares. Land falling within this category must meet its social function within a five year period, and must do so by increasing land area under cultivation by 20% per year. After five years, if it meets this objective, the owner is provided definitive title; if not, the land is expropriated for agrarian reform. Finally, definitive title is provided immediately for all landholdings 50 hectares or smaller. According to the Panamanian constitution, land under 100 hectares that is kept in production cannot be expropriated.

In 1982, under official government decree 19-650, all land along an 8 km strip on both sides of the Pan-American highway from Chepo to the Colombian border were declared State lands, accounting for most of the land in the study region. Although the Panamanian Agrarian Code expresses the rights of all Panamanians to land (article 12), and stipulates the need for a cadastral map for the entire country (article 7), such a cadastral map and registration process did not exist for much of the study area at the time of the field visits.

## Tree planting practices in Panama and Brazil

In order to understand the important factors influencing tree planting behavior on the part of small producers, two different surveys were undertaken in both Panama and Brazil between 1994 and 1996, assessing their farming practices and involvement in tree planting. The first comprised a statistical sample of households that elicited a sufficient number of responses to be used in building regression models. The second was restricted to farmers involved in tree planting. This latter sample was used to ascertain particulars of their practices, such as the tree species and quantities planted, the technology implemented (i.e. fertilizer, pesticides), and the degree of external support from both governmental and non-governmental organizations. These two studies will be elaborated, respectively, in the discussion to follow.

The Panamanian study took place along the Pan-American Highway in the Bayano Region of Panama, east of Panama City (see Figure 1 and Table 1). The study area extends from Majé located on the banks of the Bayano Lake, approximately 100 km east of Panama city, to Santa Fé, another 90 km distant. The Pan-American Highway is unpaved by the time it




reaches the Bayano Lake, from where it continues toward Colombia in bad condition. Both Panamanian samples were taken from this region, which encompasses a land area approximately 100 km long and 10 km wide.

The statistical sample in Brazil involved interviews of small producers living in the frontier reaches of the State of Pará, along a strip of the Transamazon Highway about 100 km long and 20 km wide west of the town of Altamira (see Figure 2 and Table 1). The interviews of farmers involved in tree planting were limited to an area farther to the east along PA 150, covering an area of approximately 4000 $km^2$ (400 km long and 10 km wide).

*Statistical analysis of tree planting*

In all, 356 surveys of small producers were conducted for the statistical modeling. In Panama, 95 household surveys were completed in eight communities, involving both colonist and indigenous farmers (i.e. Kuna and Embera). The sampling strategy applied a multi-stage approach, first selecting the geographically-defined communities along the Pan-American

*Table 1.* Panama study sites.

| Study Sites | Survey Instrument[a] | Approximate Distance[b] (km) | n[c] | n[d] |
|---|---|---|---|---|
| Majé | SP | 100 | 6 | – |
| La Pavita | SP | 110 | 6 | – |
| Piriatí | SP | 110 | 12 | – |
| Ipetí – Colonist | SP/TP | 125 | 10/3 | 15 |
| Ipetí – Embera | SP/TP | 125 | 10/3 | |
| Ipetí – Kuna | SP/TP | 125 | 16/4 | |
| Wacuco | TP | 132 | 1 | 1 |
| Tortí | SP/TP | 135 | 24/3 | 0 |
| IPlaya Chuso | TP | 132 | 2 | 3 |
| Higueronal | TP | 160 | 2 | 5 |
| Cañanzas | TP | 165 | 1 | 2 |
| Sante Fé | TP | 190 | 1 | 0 |
| Puerto Limon | SP | 220 | 10 | 0 |
| Total | | | 95/20 | 26 |

Source: The 95 small producer surveys (SP), selected using systematic random sampling of every fourth house, were conducted by Simmons (1994) and the 20 tree planting surveys (TP), that involved a non random sample of available respondents, were conducted by Simmons (1995). Notes: [a]Small Producer (SP) or Tree Planting (TP) interview; [b]measured from Panama City; [c]number of surveys; [d]number of reforestation events.

Highway, and then using systematic random sampling of every fourth farm to generate a 30% sample of households.[6] The Brazilian study included a sample of 261 households, and was not as systematic as the Panamanian sample due to travel distances and the dispersal of populations. As many households as could be found within the survey period were visited, and a reasonable spatial distribution of the sample was assured through daily updates of the sample map.

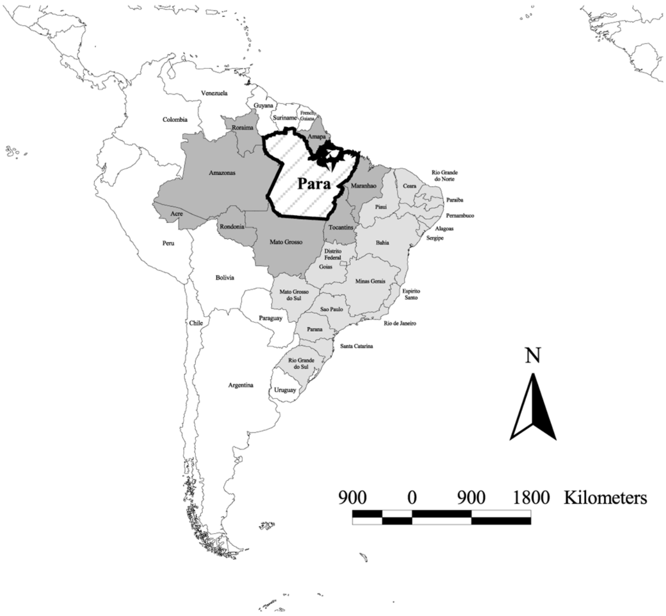
The Brazilian approach probably excludes the poorest of the farms, which are typically found in inaccessible locations. Nevertheless, farming system attributes of the Brazilian sample are similar to other samples taken from the region, suggesting that the present one is somewhat representative (Jonas da Veiga et al. 1996; Walker et al. 1997). Walker et al. (2000) and Walker et al. (2002) have conducted inferential statistics using smallholder samples collected in the way described. Altogether, the sample size used in the statistical estimation is highly comparable to other survey based studies addressing smallholder agriculture (e.g. Jones et al. (1995) and Pichón (1997)).

Both study sites are regarded as frontier regions that have been recently settled. A comparison of household characteristics revealed that, overall, small farmers in both countries are similar with respect to age, education, and family size (See Table 3). Likewise, the majority of households are involved in agricultural production as their primary activity. Analysis of the entire sample showed that about 66% of the households have some form of land tenure security, 21% plant trees, and 20% are involved in timber activities. In general, land use intensity is low in both sites. Income per hectare is 202 US$ in Panama, and 141 US$ in Brazil, while the ratios of farm land to holding size are 0.34 and 0.37, in Panama and Brazil respectively.

Nevertheless, significant differences between countries are apparent. In the Brazilian study, 58% of the households have title to their land, either legal recorded title or squatter rights.[7] Unlike Brazil, the Panamanian government has not begun the survey process for land entitlement in the study region. Consequently, none of the farmers have legal title to their land, even though, nearly all of them are confident in their squatter rights.

[6] The interval size was determined N/n, which equals 5. Any number between 1 and 4 can be used as the interval. In this study 4 was used consistently throughout the communities, which enabled every 5th house to be included in the sample. This method was used in order to prevent the surveyor from biasing results by selecting households that were convenient or farmers that may have appeared more amenable to answering questions.

[7] Squatter rights were assumed if the holder had provisional documentation from the government.


Venezuela
Guyana
Suriname
French Guiana
Colombia
Roraima
Amapa
Amazonas
Para
Maranhao
Ceara
Rio Grande do Norte
Paraiba
Pernambuco
Alagoas
Sergipe
Piaui
Acre
Rondonia
Tocantins
Peru
Mato Grosso
Bahia
Distrito Federal
Goias
Bolivia
Minas Gerais
Espirito Santo
Mato Grosso do Sul
Sao Paulo
Paraguay
Rio de Janeiro
Chile
Parana
Santa Catarina
Rio Grande do Sul
Argentina
Uruguay
N
900 0 900 1800 Kilometers

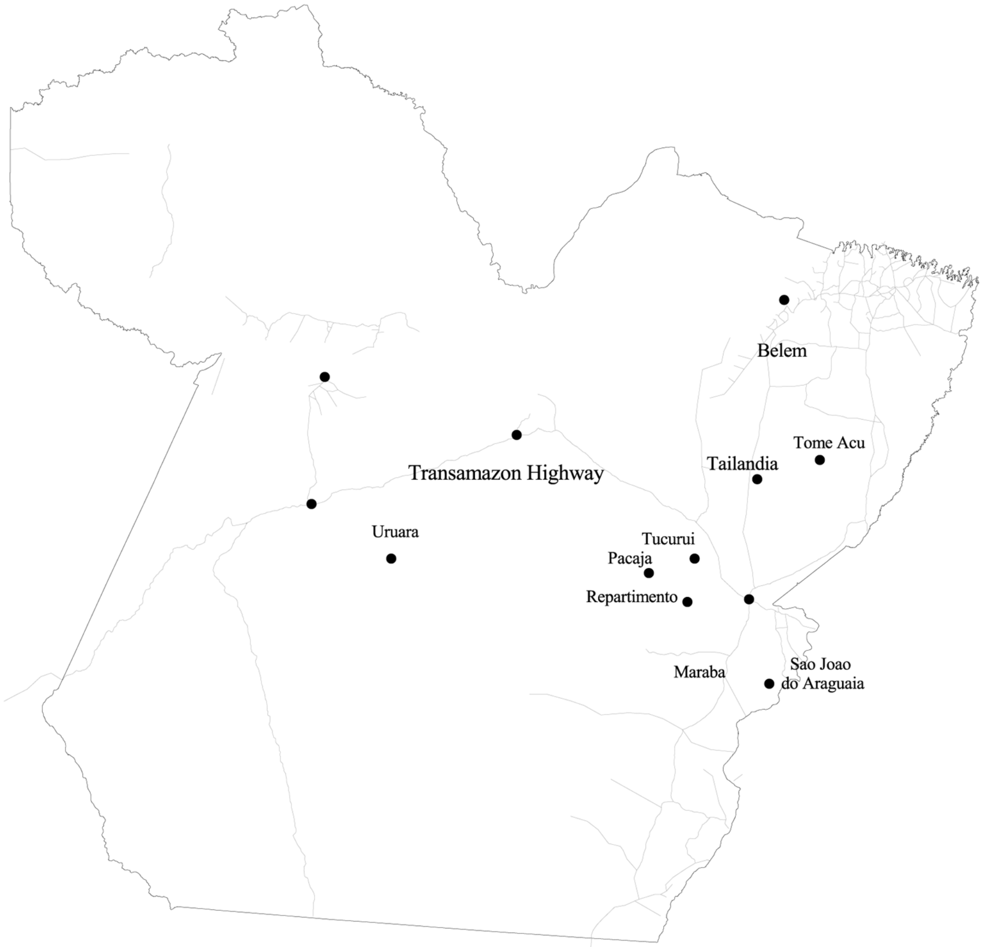

Belem
Tome Acu
Tailandia
Transamazon Highway
Uruara
Tucurui
Pacaja
Repartimento
Maraba
Sao Joao
do Araguaia

*Table 2.* Brazil study sites.

| Study Sites | Survey Instrument[a] | Approximate Distance[b] (km) | Distance[c] (km) | n[d] | n[e] |
|---|---|---|---|---|---|
| Tailândia | TP | 179 | 300 | 2 | 1 |
| Tomé Açu | TP | 150 | 375 | 4 | 18 |
| Tucuruí | TP | 300 | 210 | 1 | 4 |
| Repartimento | TP | 350 | 150 | 3 | 0 |
| Pacajá | TP | 450 | 250 | 2 | 0 |
| CAT[f] | TP | 420 | 75 | 1 | 2 |
| São João do Arguaia | TP | 480 | 40 | 2 | 4 |
| Uruará | SP | 860 | 640 | 261 | 0 |
| Totals | | | | 261 SP/ 15 TP | 29 |

Source: The 261 small producer surveys (SP), which were selected opportunistically given time constraints and distance between properties, were conducted by Walker and Wood (1996) and the 15 tree planting surveys (TP), that involved a non random sample of available respondents, were conducted by Walker (1995). Notes: [a]Small Producer (SP) or Tree Planting (TP) interview; [b]measured from Belém; [c]measured from Marabá; [d]number of surveys; [e]number of reforestation events; [f]Centro Agro-ambiental do Tocantins.

*Table 3.* Household Characteristics of Study Sample – mean

| Sample | Age | Years in School | Family Size | Family Labor Force | Farm Size (ha) | Area in Production (ha) | Ratio Farm Land to Holding | Land Use Intensity (U.S.$/ha)[a] | Tree Planting (%) |
|---|---|---|---|---|---|---|---|---|---|
| Full | 45 | 2.5 | 7.5 | 2.5 | n.a. | n.a. | n.a. | n.a. | 21 |
| Brazil | 48 | 2 | 7.7 | 2.5 | 133 | 49 | 0.37 | 141 | 8 |
| Panama | 40 | 4 | 6.5 | 2 | 29 | 10 | 0.34 | 202 | 58 |

Source: Small producer surveys for Panama (n = 95) were conducted by Simmons (1995) and Brazil (n = 261) by Walker and Wood (1996). Notes: [a]Yield ($/ha) is used as an indicator of land use intensity. For Brazil, the Real$ in 1996 was equal to the US$, and in Panama the currency is the US$.

Another apparent difference concerns participation in tree planting activities. In Panama, more than half of all households said they planted trees compared to only a few in the Brazilian sample. The majority of tree planting in the Panamanian study involved restoration tree planting of valuable hardwoods on degraded land in plantation systems, while a minority plant perennial trees (mainly fruit), and in select few cases farmers are involved in assisted natural regeneration by planting wood trees in the forest where they did selective logging. In the Brazilian sample, reforestation participation entailed the intentional planting of wood trees, mostly in agroforestry systems.[8]

An additional variation between the two study regions is the participation of households in timber activities. In Brazil, about 12% of the households are involved in logging, compared to about half of the households in Panama. This is of potential import because of legislation in Panama mandating a specified number of trees planted relative to the number cut.

Logistic regression was undertaken on the combined data from Brazil and Panama to evaluate the factors affecting small holder tree planting. Our statistical model derives from choice theory, as elaborated for the land use change case by Ludeke et al. (1990), Bockstael (1996), Chomitz and Gray (1996), Nelson and Hellerstein (1997), and others. The fundamental behavioral principle which underlies this work is that a land use will be chosen if it generates more utility than all other possible choices (Ben-Akiva and Lerman 1985). Walker et al. (2002) have extended this framework to the choice of a farming system, which is germane to the present application. In particular, the probability that farming system $i$ is selected by a small holder is Probability (selection of

[8] Agroforestry involves the intercropping of food crops with trees. Several studies have shown that agroforestry involving cacau or coffee trees with hardwoods is occurring on small farms in the Amazon region (Browder et al. 1996; Smith et al. 1996). Smith et al. (1996) notes that much of the timber trees are the result of natural regeneration.

system$i$ = prob($U_i$>$U_j$), for all $j \neq i$, where $U$ is utility, subscripted by system type.

For the case of tree planting, consider two systems, one with trees ($t$), and one without ($\sim t$). Further, let utility be resolvable into a systematic ($V$) and a random ($\epsilon$) component, or $U_i = V_i + \epsilon_i, i = t, \sim t$. Specify $V_i$ as $\beta_i x$, where $\beta_i$ is a vector of alternative specific coefficients, and $x$ is a vector of variables associated with each empirical observation. Then tree planting is observed with probability,

$$\mathrm{prob}(V_t + \epsilon_t > V_{\sim t} + \epsilon_{\sim t}). \qquad (1)$$

Note that the empirical situation of the present application is such that we do not observe discrete choices based on observable attributes of the alternatives (McFadden 1974). Instead, we observe the outcome, which is a system with or without trees, in addition to attributes of the decision-makers and the property for which the decision is made. This leads to a fixed $x$ vector, but two $\beta$ vectors associated with the two systems. In such a situation, the estimated model yields coefficients that are actually differences of the underlying $\beta$'s. Nevertheless, standard interpretations regarding relative risk still hold, as shall be shown (Hosmer and Lemeshow 1989). Continuing with the derivation, equation (1) may be written in distribution form as, $\mathrm{prob}([(\epsilon_{\sim t} - \epsilon_t) < (\beta_t - \beta_{\sim t})\mathrm{x}]) = \mathrm{F}([(\beta_t - \beta_{\sim t})\mathrm{x}])$, or $\mathrm{F}([\beta{*}x])$, where $\beta{*} = \beta_t - \beta_{\sim t}$. Assuming that $\epsilon_{\sim t}$ and $\epsilon_t$ are independent and Gumbell distributed (Ben-Akiva and Lerman 1985), we have prob(tree system selected) = $e^{\mu\beta *}/(1 + e^{\mu\beta *})$. Rewriting $\beta = \mu\beta^*$, this yields equation (1.1) in Hosmer and Lemeshow (1989), or $\mathrm{prob}(t) = e^{\beta x}/(1 + e^{\beta x})$, which can be solved for $\beta$ values using the method of maximum likelihood. The coefficients so obtained may be interpreted as the log of the "odds" ratio, which is commonly interpreted as the *relative risk* (Hosmer and Lemeshow 1989). In the present application, exponentiation of the appropriate regression coefficient provides a measure, for example, of the relative probability of tree planting with and without tenure security, or prob(tree planting, with security) / prob(tree planting, without security).

The above model was fit with maximum likelihood estimation, using SAS software. The statistical strategy was to address, through logistic regression, relationships between tree planting and the main factors considered in the discussion, namely the legal environment, land tenure security, and household attributes. The dependent variable was a categoric variable indicating if the small holder engaged in tree planting.[9] The countries themselves were taken as settings on the maturity of the institutional environment, with Panamanian sites assumed to reflect the presence of a stronger application of law and a greater availability of both markets and government support than the Brazilian study area. This was accomplished by defining dummy variables for the country associated with each survey in the database. Tenure security was also taken as a dummy variable. In the Brazilian case, tenure security was assumed to occur if owners had legal title or officially recognized *posse* (i.e. squatter's rights). In the Panamanian case, occupants confident of their squatter's rights were categorized as having tenure security.

Age of household head, length of schooling (for household head), and total household labor were taken to reflect attributes of the household. The age and education variables are indicators of human capital, which could increase the likelihood of tree planting due to environmental awareness and knowledge of tree planting techniques. The household labor force variable controls for the ability of the household to undertake investments, given the subsistence environment in which it operates (Walker and Homma 1996). Other controls for the estimation include type of farming system, participation in logging activities, and length of residence on the property.[10]

Results of the logistic regression are presented in Table 4. The results suggest a major role for the institutional, as opposed to the household, variables. The two most dramatic findings are the significant differences in tree planting between Brazil and Panama, and the importance of tenure security. As Table 4 shows, tree planting was 14.5 times more likely in Panama than in Brazil, all other variables held constant.[11] This finding supports our initial hypothesis that forestry law, market access, and government involvement in Panama may provide inducements to reforestation. Also, irrespective of country, results

[9] The dependent variable is 1 if the farmer planted trees, and 0 if not.

[10] Farming system was identified by the primary activity: 1 = agriculture; 2 = cattle; 3 = timber; 4 = perennials; and 5 = other. Timber participation is a categorical variable reflecting 1 if the household is involved in timber, and 0 if not.

[11] This is given by exponentiating the "country" coefficient, $e^{2.675} = 14.5$. The same holds for the tenure security result, $e^{2.733} = 15.4$.

*Table 4.* Logistical regression results.

Dependent Variable:
Reforestation Participation (y/n)
N: 406

| Parameters | Estimate | Probability | Odds Ratio |
|---|---|---|---|
| Country (Panama = 1; Brazil = 0) | 2.675 | 0.0001* | 14.5 |
| Tenure Security (y/n) | 2.733 | 0.0113* | 15.4 |
| Age – Head of Household | 0.016 | 0.2938 | 1.0 |
| Years in School | 0.109 | 0.1297 | 1.1 |
| Family Labor Force | 0.004 | 0.9714 | 1.0 |
| Primary Activity – Agriculture | -0.337 | 0.0546 | 0.7 |
| Year Property Acquired | -0.022 | 0.2988 | 0.9 |
| Timber Participation (y/n) | 0.572 | 0.1441 | 1.7 |

Note: Sample included 442 properties as observations derived from the 356 small producer surveys done in Panama and Brazil.

show that tenure security was an important determinant of reforestation with such activities 15.4 times more likely on land with secure tenure. Another finding, albeit less significant, was that those farmers who considered agriculture their primary economic activity were 0.7 times less likely to reforest. Timber participation, age of head of household, years in school, total family labor, and length of possession were not statistically significant (see Table 4). Overall, the goodness of fit estimation (Ben-Akiva and Lerman 1985), $\rho^2 = 1 - \iota(\beta)/\iota(0)$, yielded $\rho^2 = 0.39$, indicating a sound model; a $\rho^2$ of *0.20* or greater suggests the model is reasonably strong (Mertens and Lambin 2000).

### *Tree planting surveys*

Unlike the statistical sample, the tree planting surveys involved only 35 household surveys, registering a total of 55 reforestation *events*, individual plantings of trees by specie. The reforestation event convention is adopted since practices and government support varied by species, as did the farmer's perceptions regarding harvest horizons. The Panama study included 20 surveys from seven communities within the Bayano region (see Table 1). These interviews were conducted opportunistically, when farmers were present on their properties and willing to answer questions. The sample of twenty households registered 26 reforestation events. The Brazilian sample was composed the same way as in Panama. Household surveys were conducted in seven communities in the settlement region between the region's largest city, Belém, and Marabá (Table 2).[12] Although Tome Açu is about as far from Belém as Ipetí is from Panama City, the most distant location (São João do Araguaia) is nearly 500 km from Pará's major population concentration. Table 2 also presents distances from the sample locations and Marabá, a city of about 100,000 individuals with a long history of Brazilnut extraction and export via the Toncantins River (Homma et al. 1996). In all, interviews were conducted at 15 households in the seven communities, covering 29 instances of tree planting.

#### *Panama*

Tree planting practices in Panama focused on Teak (Tectona grandis), Cedro (Cedrela spp), and Roble (Tabebuia rosea), with some effort directed at Espinosa (scientific name unknown) and Acacia (Acacia Koa) (see Table 5a). As Table 5a shows, 10 reforestation events, more than one-third of all plantings, involved Teak. Nevertheless, the average number of Roble trees planted per reforestation event exceeds that of Teak, as do the total number of Roble trees planted in the aggregate. Table 5b shows that Roble, Espinosa, and Acacia tend to be grown from saplings, as do Teak and Cedro in most of the cases. On-site nursery production is observed in about a third of the cases excepting Espinosa and Acacia, neither of which shows nursery activity. Use of inputs, both fer-

[12] The Panamanian tree planting sample is drawn from the same population as the statistical sample. The Brazilian tree planters, although spatially distinct from the statistical sample, are smallholding colonists with highly comparable farming systems and personal characteristics.

*Table 5a.* Panamanian reforestation: species and counts.

| Species Common Name | Species Scientific Name | Number of Cases | Number of Trees | Average Planting | Minimum Planted | Maximum Planted |
|---|---|---|---|---|---|---|
| Teak | Tectona grandis | 10 | 10,195 | 1,020 | 40 | 4,000 |
| Cedro | Cedrela spp | 8 | 4,620 | 578 | 30 | 2,000 |
| Roble | Tabebuia rosea | 6 | 11,512 | 1,920 | 60 | 10,000 |
| Espinosa | unknown | 1 | 1,500 | 1,500 | | |
| Acacia | Acacia Koa | 1 | 50 | 50 | | |
| Total | | 26 | 27,877 | 1,072 | | |

Source: Simmons (1995), non-random sample of 20 tree planting surveys (TP). Notes: From the 20 surveys, 26 reforestation events were reported. The reforestation event convention is adopted since practices and government support varied by species.

*Table 5b.* Panamanian reforestation: technology.

| Species | Fertilizer Use % | Pesticide Use % | Saplings % | On-site Nursery % | External Support % |
|---|---|---|---|---|---|
| Teak | 20 | 40 | 90 | 30 | 80 |
| Cedro | 13 | 13 | 88 | 38 | 50 |
| Roble | 33 | 17 | 100 | 33 | 67 |
| Espinosa[a] | 100 | 100 | 100 | 0 | 100 |
| Acacia[a] | 0 | 0 | 100 | 0 | 100 |
| Global Frequency: | 23% | 27% | 92% | 31% | 77% |

Source: Simmons (1995), non-random sample of 20 tree planting surveys (TP). Notes: [a]Represents one case.

tilizers and pesticides, is more variable. The one reforestation event involving Espinosa utilizes both fertilizers and pesticide, while the Acacia experiment uses neither. Teak is relatively input-intensive, involving applications of both fertilizer and pesticides. On the other hand, in only one case each was pesticide used for Roble and Cedro. Fertilizer use was also low for these species, with one farmer fertilizing Cedro, and two, Roble.

Panamanian reforestation generally receives external support, mainly from government agencies (see Table 5c). More than two-thirds of all reforestation events benefited from some form of government involvement, with INRENARE (Instituto Nacional de Recursos Naturales Renovables) providing more than half of the support and IRHE (Instituto de Recursos Hidro-electrica), some additional assistance. INRENARE shows the most widespread support, and covers all tree species reforested; IRHE is somewhat more selective, and restricts its efforts to Teak and Roble. Except for the low frequency species Espinosa and Acacia, Teak tends to receive the most support, with aid from either INRENARE or IRHE. Roble also tends to be strongly supported with significant aid coming from INRENARE, and IRHE to a lesser extent.

*Table 5c.* Panamanian reforestation: agency involvement.

| Species | % INRENARE | %IRHE | %Total Support |
|---|---|---|---|
| Teak | 60 | 20 | 80 |
| Cedro | 50 | 0 | 50 |
| Roble | 50 | 17 | 67 |
| Espinosa[a] | 100 | 0 | 100 |
| Acacia[a] | 100 | 0 | 100 |

Source: Simmons (1995), non-random sample of 20 tree planting surveys (TP). Notes: [a]Represents one case.

Tree planting in Panama appears to be a recent phenomenon (see Table 5d). The overwhelming majority of all such events according to the interviews occurred between 1991 and 1995, including Teak, Roble, and Cedro plantings. For earlier years, 1980 stands out as the only other time when Teak, Cedro, and Espinosa were planted. Planting of Roble and Acacia is strictly a recent phenomenon. The Panamanian small holders show distinct planning horizons and would appear to be expecting an economic return from tree planting. Indeed, a sizeable majority of reforestation events were associated with anticipated dates, while less than a quarter were not. Most of the harvest horizons declared were of fairly long duration, considering the likely discount rates of the individuals involved (see Table 5d). Cases of Teak planting revealed harvest expectations ranging from 10 to

*Table 5d.* Panamanian reforestation: horizons and timing.

| Species | Year Planted | Harvest Horizon |
|---|---|---|
| Teak | 10% – 1980 | 40% – 10 years |
| | 90% – 1992 to 1994 | 50% – 17 to 25 years |
| | | 10% – unknown timeframe |
| Cedro | 12% – 1980 | 88% – 15 to 25 years |
| | 88% – 1991 to 1994 | 12% – unknown timeframe |
| Roble | 100% – 1991 to 1993 | 50% – 11 to 22 years |
| | | 50% – unknown timeframe |
| Espinosa | 100% – 1980 | 100% – 25 years |
| Acacia | 100% – 1993 | 100% – unknown timeframe |

Source: Simmons (1995), non-random sample of 20 tree planting surveys (TP).

25 years. Cedro planting was also a fairly long-term proposition, and a majority of respondents expected harvest coming in 15 to 25 years. The duration for Roble was similar, between 11 and 22 years.

*Brazil*

Tree planting in Brazil appears to cover a wide variety of trees with greater diversity than the Panamanian case (see Table 6a). As table 6a shows, tree planting most frequently involves Mahogany (Swietenia macrophylla) and Brazilnut (Bertholletia excelsa), although there is considerable experimentation across species. The fifteen sample households indicated attempts to plant altogether nine different types of trees. Of the total trees planted in the aggregate, Mahogany was most common, followed by Freijo (Cordia spp) and Brazilnut. With regards to greatest number of trees planted per reforestation event, Freijo planting ranks first followed by Mahogany. Other important species include Teak (Tectona grandis), Andiroba (Carapa guianensis), and lpê (Tabebuia spp.). Three reforestation events were observed each for Teak, Andiroba, and Jacaranda (Machaerium spp), although in the later case only sixty trees were planted, and only two plantings were observed for Freijo, lpê, Macacauba (Platymiscium spp), and Cedro (Cedrela spp).

As Table 6b shows, most tree planting in the Brazilian sample involves saplings, and nearly two-thirds come from on-site nurseries. However, Mahogany and Cedro depend on seeds in about half of the observed cases. In general, technological intervention in tree planting appears minimal in Brazil, with practically no use whatsoever of modern inputs. Pesticides are not used for any species, and fertilizer is applied in some Teak and Brazilnut plantings. Similarly, little institutional support is observed; less than half of the cases indicate some form of assistance, focused primarily on Mahogany and Brazilnut (see Table 6b). This support comes mainly from a number of local non-governmental organizations (NGOs), and government support for reforestation was only reported in two cases (see Table 7). In one instance, Brazil's agricultural extension agency (Empresa Brasileira de Pesquisa Agropecuaria) supported the establishment of 1300 Brazilnut trees. This species was also supported by INCRA (Instituto de Colonização e Reforma Agraria), which assisted in a small planting of 36 specimens.

As in the Panamanian case, observed tree planting is mainly a recent phenomenon, with nearly half occurring in the 1990s (see Table 6c). Nevertheless, a substantial share were planted much earlier, prior to 1980. In general, expected harvest horizons for these efforts tend to be long term. Most of the reforestation events are associated with harvest expectations in excess of 25 years, while in only few cases do farmers hope to begin cutting between 8 and 15 years. Furthermore, for many of the plantings, farmers had no expectations whatsoever. It can be inferred from Table 6c that no species pattern is evident for anticipated harvest dates, which varies considerably within species. For example, Brazilnut has a harvest horizon ranging from 8 years to 40 years. Teak also has a large harvest span ranging from 15 to 40 years. Lack of expectations are concentrated among the less frequently planted species, such as Andiroba, lpê, Macacauba, and Cedro.

## Comparison and contrast: Panama and Brazil

This paper presents results from a logistic regression, and interviews of smallholders engaged in tree planting. Overall, findings from this research point to factors that may affect tree planting across study sites in both countries, as well as those that appear to be country specific. The main cross-national result is that tenure security significantly influences tree planting behavior, which is 15.4 times more likely on land with secure tenure. Another important finding from the logistic regression was that marked differences exist between the two countries in terms of the actual likelihood of tree planting, which is 14.5 times more likely for a smallholder in Panama than in Brazil, everything else held constant. Surprisingly, household

*Table 6a.* Brazilian reforestation: species and counts.

| Species | Species Scientific Name | Number of Cases | Number of Trees | Average Planting | Minimum Planted | Maximum Planted |
|---|---|---|---|---|---|---|
| Mahogany | Swietenia macrophylla | 6 | 6,465 | 1,078 | 20 | 5,000 |
| Brazil Nut | Bertholletia excelsa | 6 | 3,472 | 579 | 16 | 2,000 |
| Teak | Tectona grandis | 3 | 2,400 | 800 | 200 | 1,700 |
| Andiroba | Carapa guianensis | 3 | 700 | 234 | 100 | 500 |
| Jacaranda | Machaerium spp | 3 | 60 | 20 | 10 | 50 |
| Freijo | Cordia spp | 2 | 3,500 | 1,750 | n.a. | 3,500 |
| Ipê | Tabebuia spp | 2 | 600 | 300 | 50 | 550 |
| Macacauba | Platymiscium spp | 2 | 150 | 75 | 50 | 100 |
| Cedro | Cedrela spp | 2 | 54 | 27 | 4 | 50 |
| Total | | 29 | 17,401 | 600 | | |

Source: Walker (1995), non-random sample of 15 tree planting surveys (TP). Notes: From the 15 surveys, 29 reforestation events were reported. The reforestation event convention is adopted since practices and government support varied by species.

*Table 6b.* Brazilian reforestation: technology.

| Species | Fertilizer Use% | Pesticide Use % | Saplings % | On-site Nursery % | External Support % |
|---|---|---|---|---|---|
| Mahogany | 0 | 0 | 50 | 67 | 83 |
| Brazil Nut | 17 | 0 | 100 | 50 | 83 |
| Teak | 33 | 0 | 100 | 100 | 0 |
| Andiroba | 0 | 0 | 100 | 100 | 33 |
| Jacaranda | 0 | 0 | 100 | 100 | 33 |
| Freijo | 0 | 0 | 100 | 0 | 0 |
| Ipê | 0 | 0 | 100 | 100 | 0 |
| Macacauba | 0 | 0 | 100 | 100 | 0 |
| Cedro | 0 | 0 | 50 | 50 | 0 |
| Global Frequency: | 7% | 0% | 86% | 69% | 41% |

Source: Walker (1995), non-random sample of 15 tree planting surveys (TP).

and farming system variables did not show much influence.

Although the regression results provide significant insight into the factors that may encourage tree planting on the part of small farmers, they cannot answer why or how these activities vary between the two countries. To gain insight into such issues we can refer to the tree planting interviews; however, any interpretation can only be taken as suggestive given the small sample size. That having been said, one possible conclusion is that tree planting in Panama appears to be more intensive and market-driven than in Brazil. Panamanian efforts show use of fertilizer and pesticides, while Brazilian farmers use little fertilizer and no pesticides. Cleaning of reforestation areas is also more common in Panama than in Brazil. Such technological differences may be linked to the tree planting systems utilized. In Panama, most tree planting occurs in plantation-style mono-cropping, which requires regular maintenance. In Brazil, however, about half of the reforestation events occur in combination with perennials such as coffee and cacao. Conse-

*Table 6c.* Brazilian reforestation: horizons and timing.

| Species | Year Planted | Harvest Horizon |
|---|---|---|
| Mahogany | 17% – 1975 | 67% – 36 to 50 years |
| | 83% – 1991 to 1995 | 33% – unknown |
| Brazil Nut | 17% – 1975 | 50% – 8 to 12 years |
| | 17% – 1980 | 17% – 40 plus years |
| | 66% – 1991 to 1995 | 33% – unknown timeframe |
| Teak | 100% – 1994 to 1995 | 33% – 15 years |
| | | 67% – 40 plus years |
| Andiroba | 100% – 1975 | 100% – unknown timeframe |
| Freijo | 100% – 1973 | 100% – 37 to 52 years |
| Ipê | 50% – 1975 to 1980 | 50% – 50 years |
| | 50% – 1985 to 1994 | 50% – unknown timeframe |
| Macacauba | 100% – 1975 | 50% – 30 years |
| | | 50% – unknown timeframe |
| Cedro | 50% – 1980 | 50% – 30 years |
| | 50% – n.a. | 50% – unknown timeframe |

Source: Walker (1995), non-random sample of 15 tree planting surveys (TP).

*Table 7.* External support: Panama and Brazil

| Agency Support | Percentage of Cases |
|---|---|
| Panama | |
| INRENARE[a] | 19 |
| IRHE[a] | 19 |
| None | 23 |
| Brazil | |
| CAT | 7.0 |
| CESPASP | 3.3 |
| FATA | 3.3 |
| INATAM | 3.3 |
| Tucurui Syndicate | 7.0 |
| SAGRI | 3.3 |
| Camta Cooperative | 7.0 |
| INCRA[a] | 3.4 |
| EMBRAPA[a] | 3.5 |
| None | 59 |

Source: Simmons (1995), non-random sample of 20 tree planting surveys for Panama. Walker (1995), non-random sample of 15 tree planting surveys in Brazil. Notes: [a]Government Agencies

quently, cleaning occurs with the harvest of the agricultural crops, whose by-products provide some organic fertilizers.

Another difference relates to species and expected harvest horizons. Panamanians focus on three species of known value (teak, cedro, and roble), while Brazilians are more experimental and presently work with nine species. In Panama, the majority of the observed reforestation events showed a distinct harvest horizon, while in Brazil this occurred in about one-third of the cases. Further, Panamanian farmers expect short to mid-term returns, in contrast to the very long horizon in Brazil. Moreover, harvest horizons in Panama show consistency by species; in Brazil they vary widely. Teak reforestation in Brazil for example shows harvest expectations ranging from 15 to 40. In Panama they are considerably less variable (10 to 25 years). This suggests greater awareness of market situation in Panama, and perhaps greater opportunity.

Panamanian tree planting efforts appear to be more technologically sound than the Brazilian case. The difference in the knowledge base may be due to the varying degrees of external support provided for reforestation (see Table 7). In Panama, most tree planting involved government support with either technological and/or material dissemination. However, Brazilian planting activities benefit from some support provided by non-governmental organizations, and very limited assistance from government agencies.

An additional factor to consider is location, which affects opportunities for technological and material extension, as well the strength of market forces. The Bayano Region of Panama is comparatively small and relatively more accessible than the study region in Brazil. Most of the communities visited cluster around the Pan-American Highway, which is passable during most of the year. The ease of access to these remote communities facilitates extension outreach and forest management, as well as market incentives for wood production. The Brazilian region, in contrast, is much larger and communities are highly dispersed; moreover, the highway system is poorly maintained and only parts of it are passable during the rainy season.

## Conclusions

This paper has highlighted two important factors influencing small farmer tree planting behavior, namely tenure security and government involvement. The logistic regression showed that a statistically significant relationship exists between tree planting and tenure security across the study sites. It also demonstrated that country specific differences exist, with more reforestation occurring in Panama than in Brazil. Although both countries provide incentives for tree planting directed at large scale corporate interest, the tree planting interviews in Panama revealed that government assistance in the form of technology and materials (i.e. seeds, fertilizer, pesticide) has encouraged such activities.

Another factor that may explain differences between the study regions relates to Panamanian regulation requiring reforestation in return for timber extraction; the small producer surveys revealed that substantially more Panamanian farmers are involved in logging, hence tree planting. Finally, location is an essential force to consider. The Bayano region of Panama is generally more accessible than the Brazil study sites, and, as a result, timber markets are closer and technological and material dissemination is facilitated.

Overall, it is clear from the surveys that small farmers in both countries are actively engaged in such tree planting activities, despite protracted returns on investment. Even though expected profit was an important determinant in Panama, respondents in both

countries suggested that the amenity value provided by trees and the desire to leave a natural bequest for future generations were the primary motivations behind their actions.

Tree planting will not compensate for biodiversity loss resulting from the initial deforestation of primary tropical forest; however, such efforts can conceivably reduce the demand for new lands, minimize the degree of ecological disturbance at farm site, and enhance land values. Consequently, such efforts should be encouraged. Additional governmental and non-governmental involvement in delivering technical and material support to small farmers, together with the provision of land tenure security, could provide the basis for a successful policy aimed at reforestation and the restoration of degraded lands in the tropical forest biomes of Central and South America.

## Acknowledgements

This research was supported by the International Institute of Tropical Forestry, U.S. Forest Service, and we are grateful to Dr. Fred Scatena and Dr. Ariel Lugo for their encouragement and interest. Additional Support was also provided by the Florida State University Committee on Faculty Research Support, and Council on Research and Creativity, as well as by the National Science Foundation (under SBR-95-11965). Dr. Adilson Serrão, Director of EMBRAPA/CPATU, provided generous logistical assistance. Dr. Rick Condit and Dr. Stanely Heckadon of the Smithsonian Tropical Research Institute (STRI), helped greatly in the logistical aspects of the work in Panama. In addition, we are especially grateful to Salamon Aguilar (STRI) and Rotilio Paredes (PEMASKY) for their excellent field assistance in Panama, and Dionesio Bautista and Ulises Morales of IUCN, Francisco Herrera of the University of Panama, Mirei Endara of INRENARE, Atencio Lopez and Marcial Arias of NAPWANA, Cacique Bonarjes of the Ipeti Embera Community, Cacique Dilmo Mecha of the Maje Embera Community, Cacique Tomas of the Comarca Madugandi for their valuable insight.

## References

Allan W. 1965. The African Husbandman. Barnes and Noble, Inc., New York, USA.

Alston L.J., Libecap G.D. and Mueller B. 2000. Land reform policies, the sources of violent conflict, and implication for deforestation in the Brazilian Amazon. Journal of Environmental Economics and Management 39(2): 162–188.

Alves D.S. and Skole D.L. 1996. Characterizing land cover dynamics using multi-temporal imagery. International Journal of Remote Sensing 17(4): 835–839.

Balee W. 1992. People of the fallow: A historical ecology of foraging in lowland South America. In: Redford K.H. and Padoch C. (eds), Conservation of Neotropical Forests. Columbia University Press, New York, USA, pp. 35–57.

Ben-Akiva M. and Lerman S.R. 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT Press, Cambridge, MA, USA.

Bockstael N.E. 1996. Modeling economics and ecology: The importance of a spatial perspective. American Journal of Agricultural Economics 78: 1168–1180.

Browder J.O., Matricardi E.A.T and Abdala W.S 1996. Is sustainable tropical timber production financially viable? A comparative analysis of mahogany silviculture among small farmers in the Brazilian Amazon. Ecological Economics 16(2): 147–159.

Brown S. and Lugo A. 1990. Tropical secondary forests. Journal of Tropical Ecology 6: 1–32.

Cernea M. 1989. User Groups as Producers in Participatory Afforestation Strategies. World Bank Discussion Papers, 70th edn. The World Bank, Washington, DC, USA.

Chomitz K.M. and Gray D.A. 1996. Roads, land use, and deforstation: a spatial model applied to Belize. The World Bank Economic Review 10(3): 487–512.

Ellis F. 1993. Peasant Economics. Cambridge University Press, Cambridge, UK.

Fortmann L. 1985. The tree tenure factor in agroforestry with particular reference to Africa. Agroforestry Systems 2: 253–272.

Godoy R.A. 1992. Determinants of smallholder commercial tree cultivation. World Development 20: 713–725.

Hirshleifer J. 1970. Investment, Interest, and Capital. Prentice-Hall, Englewood Cliffs, NJ, USA.

Homma A., Walker R.T., Carvalho R., Jose de Conta A., Ferreira C. and Palheta A. 1996. Razoes de risco e rentabilidade na destruicao de recursos florestais: 0 caso de castanhais em lotes de colonos no Sul do Para. Revista Economica do Nordeste 27(2): 515–535.

Hosmer D.W. and Lemeshow S. 1989. Applied Logistic Regression. John Wiley and Sons, New York, USA.

Jonas da Veiga J., Tourrand J. and Quanz D. 1996. A Pecuária na Fronteira Agrícola da Amazônia: O Caso do Municipio de Uruará, PA, na Região da Transamazônica. Documentos 87th edn. EMBRAPA/CPATU, Belém, PA, Brazil.

Jones D.W., Dale V.H., Beauchamp J.J., Pedlowski M.A. and O'Neill R.V. 1995. Farming in Rondonia. Resource and Energy Economics 17: 155–188.

Ludeke A.K., Magio R.C. and Reid L.M. 1990. An analysis of anthropogenic deforestation using logistic regression and GIS. Journal of Environmental Management 32: 247–259.

Machado P.A.L. 1995. Direito Ambiental Brasileiro. 5th edn. Malheiros Editores Ltda., Sao Paulo, Brazil.

McFadden D. 1974. The measurement of urban travel demand. Journal of Public Economics 3: 303–328.

Mertens B and Lambin E.F. 2000. Land-cover-change trajectories in southern Cameroon. Annals Of The Association Of American Geographers 90(3): 467–494.

Mitra T. and Wan H.Y. 1985. Some theoretical results on the economics of forestry. Review of Economic Studies 52: 263–282.
Moran E.F., Packer A., Brondizio E. and Tucker J. 1996. Restoration of vegetation cover in the eastern Amazon. Ecological Economics 18: 41–54.
Nelson G.C. and Hellerstein D. 1997. Do roads cause deforestation? Using satellite images in econometric analysis of land use. American Journal of Agricultural Economics 79: 80–88.
Ostrom E. 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, New York, USA.
Pichón F.J. 1997. Settler households and land-use pattern in the Amazon frontier: Farm-level evidence from Ecuador. World Development 25(1): 67–91.
Raintree J.B. 1987. Land, Trees, and Tenure. International Council for Research on Agroforestry: Nairobi and the Land Tenure Center, Madison, WI, USA.
Rudel T. 1997. The paths to rain forest destruction: Cross-national patterns of tropical deforestation. World Development 25: 53–65.
Saldarriaga J.G., West D.C., Tharp M.L. and Uhl C. 1988. Long-term chronosequence of forest succession in the upper Rio Negro of Colombia and Venezuela. Journal of Ecology 76: 938–958.
Saldarriaga J.G. and Uhl C. 1990. Recovery of forest vegetation following slash-and-burn agriculture in the upper Rio Negro. In: Gomez-Pompa A., Whitmore T.C. and Hadley M. (eds), Rain Forest Regeneration and Management. UNESCO and The Parthenon Publishing Group, Paris, France, pp. 303–312.
Simmons C.S. 1997. Forest magagement practices in the Bayano region of Panama: Cultural variations. World Development 25(6): 989–1000.
Singh I., Squire L. and Strauss J. 1986. The basic model: Theory, empirical results, and policy considerations. In: Singh I., Squire L. and Strauss J. (eds), Agricultural Household Models. Johns Hopkins University Press, Baltimore, USA, pp. 17–47.
Smith N.J.H, Falesi I.C., Alvim P.D. and Serrao E.A.S. 1996. Agroforestry trajectories among smallholders in the Brazilian Amazon: Innovation and resiliency in pioneer and older settled areas. Ecological Economics 18(1): 15–27.
Thacher T., Lee D.R. and Schelhas J.W. 1997. Farmer participation in reforestation incentive programs in Costa Rica. Agroforestry Systems 35: 269–289.
Thorner D., Kerblay B. and Smith R.E.F. 1986. A.V. Chayanov on the Theory of Peasant Economy. University of Wisconsin Press, Madison, WI, USA.
Uhl C. 1987. Factors controlling succession following slash-andbum agriculture in Amazonia. Journal of Ecology 75: 377–407.
Unruh J.D. 1995. Agroforestry, reforestry, and the carbon problem: The role of land and tree tenure. Interdisciplinary Science Review 20(3): 215–227.
Uphoff N. 1986. Local Institutional Development: An Analytical Sourcebook, with Cases. Kumarian Press, West Hartford, USA.
Vieira I.C.G., Salomao R., Roas N., Nepstad D. and Roma J. 1996. 0 renascimento da floresta no rastro da Agricultura 20(119): 38–44.
Walker R.T., Perz S., Caldas M. and Texeira da Silva L.G. 2002. Land Use and Land Cover Change in Forest Frontiers: The Role of Household Life Cycles. International Regional Science Review 25(2): 169–199.
Walker R.T. 1993. Deforestation and economic development. Canadian Journal of Regional Science 16: 481–497.
Walker R.T. 1999. The structure of uncultivated wilderness: Land use beyond the extensive margin. Journal of Regional Science 39(2): 387–410.
Walker R.T. and Homma A.K.O. 1996. Land use and land cover dynamics in the Brazilian Amazon: An Overview. Ecological Economics 18: 67–80.
Walker R.T. and Wood C. 1998. Conserving the Tropical Resource Base: Do We Title Land or Organize Community? Florida State University, Tallahassee, USA (unpublished).
Walker R.T., Homma A., Conto A., Carvalho, Ferreira C., Santos A. et al. 1997. As contradições do processo de desenvolvimento agrícolo na Transamazon – Contradictions in the Process of Agricultural Development along the Transamazon Highway, EMBRAPA Document # 93. EMBRAPA-CPATU, Belém, Brazil.
Walters B.B. 1997. Human ecological questions for tropical restoration: experiences from planting native upland trees and mangroves in the Philippines. Forestry Ecology and Management 99: 275–290.
Walters B.B., Cadelina A., Cardano A. and Visitacion E. 1999. Community history and rural development: Why some farmers participate more readily than others. Agricultural Systems 59(2): 193–214.
White T.A. and Runge C.F. 1994. Common property and collective action: Lessons form cooperative watershed management in Haiti. Economic Development and Cultural Change 43: 1–41.
Walker R.T. 1987. Land use transition and deforestation in developing countries. Geographical Analysis 19(1): 18–30.
Walker R.T., Moran E. and Anselin L. 2000. Deforestation and cattle ranching in the Brazilian Amazon: External capital and household processes. World Development 28(4): 683–699.